Implementation of Source Engine for Virtual Tours in Manufacturing Factories

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Abstract. When we discuss virtual reality as a medium, there are two main genres: virtual tour and virtual training. This paper deals with the use of virtual reality for interactive virtual tours in manufacturing factories. We developed a brand new software **package/library DIGITOV** which serves as an aid for constructing new virtual interactive manufacturing factory models using Source Engine. This graphic engine is known for its use in the Half-Life 2 computer game [1]. One of the general advantages of adapting this engine is the public availability of the powerful development software tools included in the Source SDK. While adapting the engine to a new environment it is necessary to prepare a library consisting of many new 3D models, textures, sounds, choreographed scenes etc. The package includes for instance: machines, products, parts of a manufacturing line, specific sounds etc.

1 Introduction

We can observe a visible trend of penetration of virtual reality into everyday praxis. Many industrial corporations have their own concept of a digital factory: all the aspects of manufacturing are digitally verified on digital mock-ups before physical manufacturing. This approach brings significant cost savings. Virtual reality is used mainly in the validation phase; for example, verifying the design and functionality of a digital prototype, the driving properties of a physically non-existing car, ergonomics of a workplace etc. We will focus on the validation of manufacturing companies' layout and employee training. Using the further described virtual tours it is possible to visualize the whole factory including administration space, validate the perspective for working activities, have a virtual discussion with guides, etc. Generally it is possible to perform many more interactive actions in a customizable environment. All the virtual tours can be practically made using stereoscopic projection in a CAVE (Computer Aided Virtual Environment) using a haptic controller (see Fig. 1). There is a possibility of using supported DirectX stereoscopy with the Razor Hydra controller.

There are several software tools for modeling digital factories with the possibility of adding models from a 3D library to user composition. Two of today's major solutions are the Dassault Systeme DELMIA and Siemens Tecnomatix. These can be used to perform a large number of analyses [2]. From these two packs the full virtual tour

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in CAVE can be provided by Teamcenter VisMockUp software but with limited interaction. The other suitable tool is VisTable which natively supports a virtual tour but without the possibility of interacting with the virtual world.

All the universal software tools for virtual environment development are relatively expensive. This is why we have been searching for a way to use a widely spread environment for enterprise and factory design. From the practical side: we were also looking for a modular possibility in order to develop a universal learning tool for a virtual world design course for industrial engineers. After researching more possibilities we have chosen to modify Source Engine. Its single non-commercial license costs about €10.

Fig. 1. Target single-screen CAVE with IS-900 tracking device

2 Serious Games

Our system (see below) uses the principles of serious gaming. This term relates to specific interactive simulations where the main reason is not only to entertain, but also to educate the user or engage him/her in solving particular problems. A certain amount of fun while playing is required, though. One of the first applications of serious gaming came from the army. There is for example a free game by America's Army for training soldiers and advertising [3]. Another technically simpler game is for example Food Force. It was developed by the United Nations and informs about famine in the world [4].

Serious games, like any other computer game, can be developed from scratch using conventional programming environments or with the aid of so called 'sandbox'

programs. These programs can be used to accelerate the development of virtual environments with the possibility of implementing interactive elements. 2D or 3D objects can usually be imported from standard formats, the interactive elements are implemented by block programming or scripting. Some examples of stand-alone sandbox solutions are Thinking Worlds, WinterMute Engine, Unity3D or VirTools (with native supports of multicluster visualization in CAVE). Another possibility is the use of game editors made by game developers simultaneously with the engine (which is the case described in this paper).

Adaptation of standard game engines for serious games is very frequent. For example, CryEngine has been successfully adapted for training Dubai's S.W.A.T police commandos [5], the US Army [6] and even as a surgery simulator [7]. Source Engine was used for example for a restaurant hygiene simulator [8] and other serious games.

3 Source Engine and Source SDK

Another implementation described here uses **Source Engine**, which is a modular game engine for PC, Linux, Mac OS, PS3 and Xbox. Source Engine was released in 2004 for the computer game Counter-Strike: Source, and then for Half-Life 2 one year later. Source is a high-quality graphics core with simulated physical systems support using the Havok engine. Source engine is based on the DirectX architecture with the possibility of High Dynamic Range. More features such as multicore rendering support, Hardware Facial Animation, "Soft" particles, etc. have recently been added [9].

The virtual environment is built by a **map** (or level). The virtual world can be comprised of more interconnected maps. All particular environments are limited to a user-defined enclosed volume which is composed of **brushes**. Brushes are basic 3D objects that represent walls, floors, ceilings, cliffs, terrain, etc. The world details: e.g. furniture, humans, trees or sometimes even whole buildings (with esthetic functionality only) are represented by **3D models** (static, dynamic and physical props). Brushes are objects of lower detail than 3D models and are modeled and edited directly in Source SDK enclosed tools. On the other hand, 3D models are modeled using complex 3D editing tools like 3DS MAX, Blender or XSI SoftImage and then imported to a Source based map. All items and NPCs (Non-Player Characters) are represented by detailed 3D models. Functional parts of maps are implemented by so-called **entities** (doors, lifts, switches, light control, any mathematical or physical logic, etc.).

Every virtual environment developed in Source Engine is physically stored in a specific directory structure which includes for instance these components (directories):

- Maps – all maps are stored here (BSP - Binary Space Partitioning format)
- Materials – contains all textures (VTF – Valve texture File) including a material description file in text format (VMF – Valve Material File)
- Models – all the detailed 3D models (MDL format). Only special textures from Materials directory can be used for models.

- Scenes – scripted scenes data (choreography) created by the FacePoser tool which is included in the Source SDK
- Sound – sounds in WAV format

This structure can be compiled into a single .gfc archive. There is also a possibility to inherit data from other modifications (adapted Source Engine packs) or Source powered games. In other words, it is possible to use all previously designed models, textures, NPCs, etc.

Components of the virtual environments in Source Engine are created and edited using the Source SDK which is a powerful development package tool which can be downloaded via the Steam distribution system by the owner of a valid Source engine game (like Half Life 2). This environment includes a possibility of new modification (so called 'mods') development. Within or without this modification a new map can be developed. There is also a tool for new map creation called **Hammer Editor**. Software tool FacePoser can be used for creating choreographed scenes including face mimics and lips to sound synchronization. There are a lot of other tools included, usually file format converters, such as image to VTF (Valve Texture File) and many more. The source code of the engine is included, so the possibilities are virtually unlimited.

4 Reference Model

First a reference model was created in order to validate the possibility of developing such complex models in the given engine.

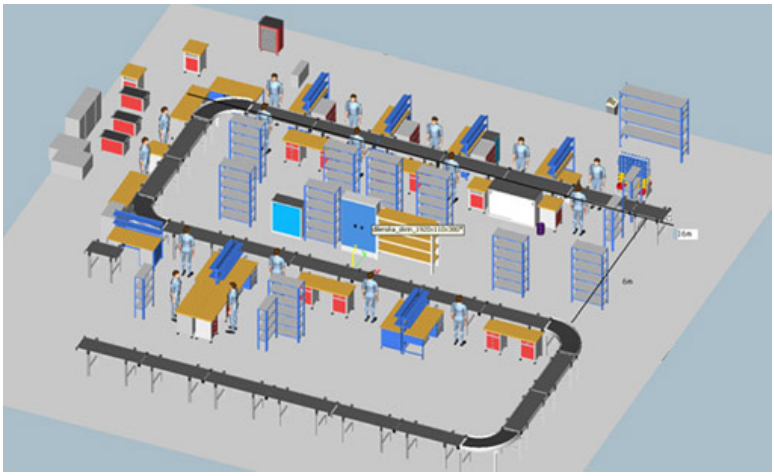

Fig. 2. Manufacturing layout of a reference model (in Siemens NX)

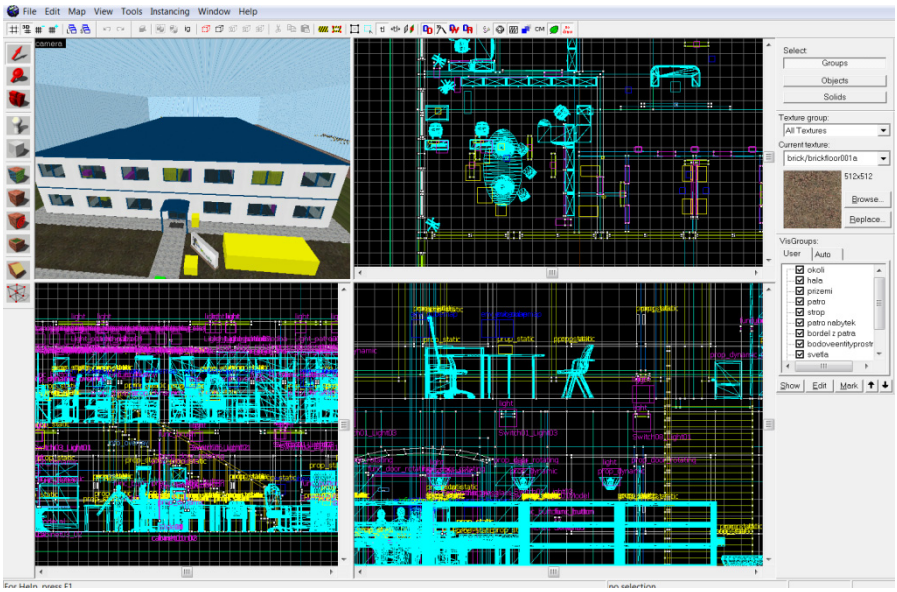

Fig. 3. Example of the development of the first reference model

An extensive virtual re-engineering project was used as an ideological base. In this project each step of the referential product (RC car) production planning was digitally composed starting with a raw design and ending with assembly line simulation optimization. All the production data including 2D and 3D layout from the Technomatix software package were available (such as 3D layout in Fig. 2). The assembly line was re-created using the Source SDK tools. The project output data also helped with construction of other non-manufacturing facilities (offices, canteen, toilets, exterior etc.). Simple interactive features were implemented, such as switchable lights, doors, ladders, etc. More complex interactivity was also added: e.g. the conveyor belts control, interaction with the operators and choreographed scenes with the virtual actors (mentors) in general.

During the development (see Fig. 3) it was revealed that the number and type of models and textures included in the original core was not sufficient. 3D models of workshop and office furniture, machines, IT equipment, etc, were missing. Based on the original gaming purpose, it is clear that the original includes models and textures which are supposed to immerse the user in a thrilling atmosphere, for example the furniture is sometimes half-broken and the walls are dirty, ergo they were not suitable to be used for our case.

5 DIGITOV Package

The evaluation of the development, implementation and validation process of the referential model raised the need for new content. So as to be able to effectively create new virtual models of manufacturing factories, it was necessary to produce a

brand new library comprising 3D models, textures, interactive features and so called in Source SDK **prefabs** (logically grouped brushes, entities and 3D models). Some of these were created while working on the reference model. In order to maximize the modularity of the "building set", a lot more of such components were needed to be added. The DIGITOV modification for the computer game Half-Life 2: Episode Two started to take form. This is not a standard game modification, like a new story, but a collection of components for developers of virtual enterprise environments. The package includes an automatic installer developed in Delphi. There is just one requirement for the DIGITOV package to work: to own a user license for the Half-Life 2: Episode Two computer game, preferably in the Orange Box edition.

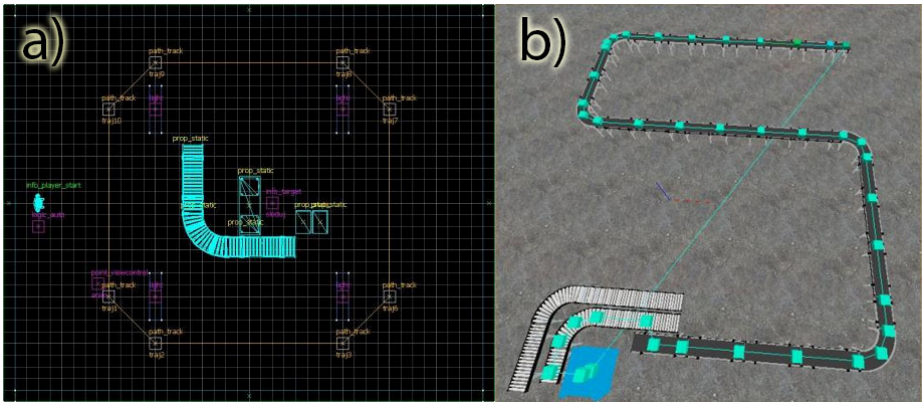

Fig. 4. a) conveyor belt curve prefab, b) conveyor belt constructed from prefabs in Hammer Editor

The DIGITOV currently contains approximately 150 new 3D models, more than 50 textures for models, more than 50 textures for maps and more than 25 static and dynamic prefabs. Static prefabs represent usually concrete or brick blocks with/without windows/doors, from which a raw factory layout could be composed. Dynamic prefabs are sets of prepared interactive aggregations. One example of dynamic prefabs from the DIGITOV package could be particular active parts of a conveyor belt (start/end, straight, curve, T-shape part, etc.), where besides the model and track path are also defined points where the product model is transformed (assembled), where the belt can be connected to another part of the belt, where the operator performs interactions etc. (see Fig. 4)

The package also contains various predefined choreographed scenes with virtual employees like various types of greetings, mentoring, presentations and more. These can be assembled into arbitrary sequences in the level editor. The original virtual actors' clothes were "virtually cleaned and ironed" (see Fig. 5-a). All these choreographic scenes were prepared using the FacePoser tool, where the particular face mimics and speech is synchronized and composed into replicas in a timeline (see Fig. 5-b). For English language Microsoft Speech SDK can be used for automatic mimic and voice synchronization. For other languages time consuming manual synchronization has to be done.

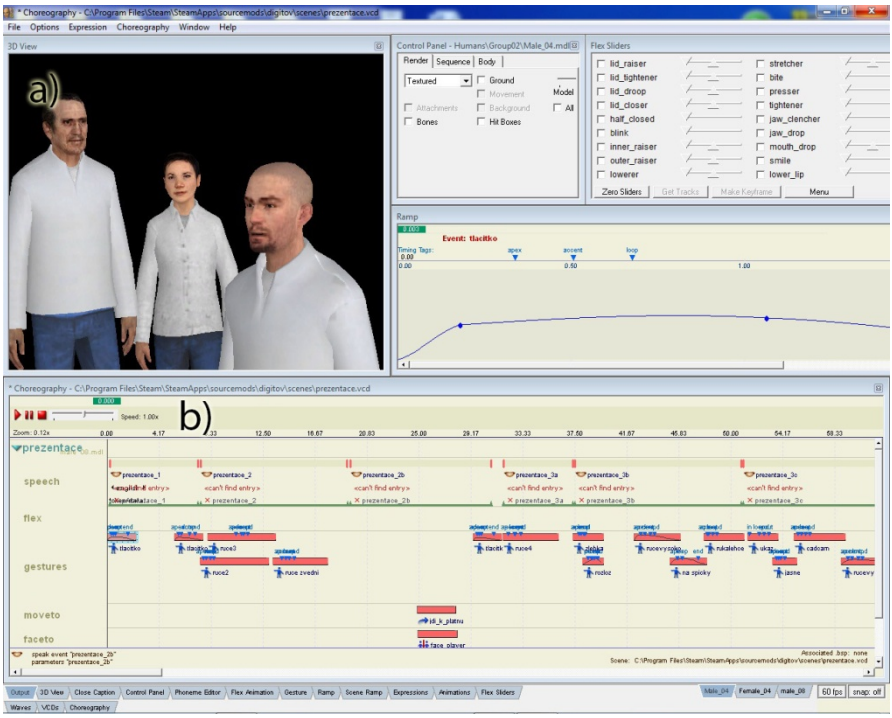

Fig. 5. a) Re-skinned NPC employees in Face Poser, b) Action editor

The DIGITOV package is installed in the modifications folder. While launching the Source SDK tool, the DIGITOV mod can be simply selected from the menu instead of the default Source Engine 2009, then all the additional options are available in the Valve Hammer Editor.

6 An Example of DIGITOV Package Implementation

Let us show one of the virtual enterprise models which was designed with the aid of the DIGITOV package from a user point of view.

The first person camera perspective view of the model is shown just after the virtual environment has been loaded. The control system help is displayed immediately after loading the model. The user has a complete mouse and keyboard controlled freedom of movement. The right mouse key serves for displaying labels or hints - mainly for interactive elements (like offices, persons, products, etc.). This feature is very useful for instance for key elements of conveyor belt inspection.

While taking a tour in one of the models the user follows a storyboard (see Fig. 6):

a) External view of the manufacturing enterprise. It is possible to examine the parking lot, climb up on to the roof. Let us take a look inside,

Fig. 6. Storyboard

b) where the user is welcomed. A virtual lady will take us to the presentation room,
c) where the lecturer will show us some basics of the production in this factory (this presentation is more than 10 minutes long, but can be skipped)
d) then the user is brought to the manufacturing section. Each particular section of the manufacturing process can be inspected.
e) The user can also be familiarized with the functions of every single administrative office in the administrative part of building.
f) The manufacturing section can be observed from a bird's-eye view.

7 Validation, Conclusion and Results

The developed package is an alternative to other enterprise design software. It is a convenient tool not only for students, but can be used also for commercial use (a valid commercial license needs to be purchased by an enterprise). It can be used for instance to show the factory to new employees, who are recruited in another part of the world or for common visualization of not yet existing enterprise buildings for many reasons.

A manual and an education e-book (with more than 200 pages) were written alongside development. 14 authors spent 3 years developing DIGITOV and the e-book.

The ready-to-use package has been used for making 15 complex virtual enterprise models; two of them were models of real factories, validated by its staff; two more models of residential houses and a partial model of a university building. More reusable assets were designed and added to the package during the development of the models.

In comparison with large commercial tools for factory design like Delmia, Tecnomatix or Autodesk Factory CAD the proposed package does not offer the option to perform analyses of material flow, capacity tasks, ergonomics task, etc. but the DIGITOV package has advantages in better visualization, solution of training tasks and user interactivity implementation with low-cost. Industrial engineers who were approached reacted very positively to the presentation power and high fidelity of simulation. DIGITOV offers an assets library which can compete with factory design software packages.

Right now with the DIGITOV package and a little experience a fully interactive factory design can be produced in a few hours. For example, in comparison with DELMIA, the same factory layout was developed in half the time.

The DIGITOV package successfully supports the lessons of the "Digital enterprise and virtual reality" subject (so far for two years). The students are shown the basics of developing virtual worlds. The package is also being used for lessons at the "Summer school of virtual reality" for high school students.

The environments can be viewed stereoscopically on a 3D monitor or in CAVE. The virtual world can be controlled using a keyboard and a mouse or with a special Razor Hydra controller 9, where a sensor monitors the position of the special controllers in both hands via a magnetic field. The right location has to be found while using this controller in CAVE because of possible interference issues.

Although the DIGITOV package represents a powerful alternative tool for making mock-ups of virtual enterprises, there are still some ideas for improvement, such as:

- Dynamic animations in some models are missing.
- The map must be run from the console using the "map" command – a GUI launcher would be suitable.
- Interactive height selection of the player in order to verify the working positions perspective for different operator heights.

One of these recently corrected imperfections was the low count of textures. Volunteers searched the internet for usable free textures. Then a texture service pack was released containing more than 1000. Another recent validated potency is the possibility of adding more remote host users into a map and then to arrange off-distance briefings in a virtual factory.

The main point of the subsequent research is to develop a convertor, which will automatically convert a factory model from VisTable software into DIGITOV ready maps.

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